Newton's Laws

1) Use Newton's first law to explain why
   (a) steel barriers usually separate the cab of a truck from the load,
   (b) trucks carrying tall loads navigate corners slowly, and
   (c) customers who order take-out drinks are provided with lids.

2) Imagine you are the hockey coach for a team of 10-year-olds. At a hockey practice, you ask the players to skate across the ice along the blue line (the line closest to the net), and shoot the puck into the empty net. Most of the shots miss the net. The faster the children skate, the more they miss. Newton's first law would help the players understand the problem, but a technical explanation might confuse them.
   (a) Create an explanation that would make sense to the 10-year-olds.
   (b) With the aid of a diagram, design a drill for the team that would help the players score in this type of situation.

3) What is the difference between a net force and an applied force? Can a net force ever equal an applied force? Explain using an example and a free-body diagram.

4) What happens to the acceleration of an object if
   (a) the mass and net force both decrease by a factor of 4?
   (b) the mass and net force both increase by a factor of 4?
   (c) the mass increases by a factor of 4, but the net force decreases by the same factor?
   (d) the mass decreases by a factor of 4, and the net force is zero?

5) The net force acting on a 6.0-kg grocery cart is 12 N [left]. Calculate the acceleration of the cart. [2.0 m/s^2 [left]]

+ ←

$\vec{F}_{NET} = 12\,N$
$m = 6.0\,kg$
$\vec{a} = ?$

$\vec{F}_{NET} = m\vec{a}$

$\frac{\vec{F}_{NET}}{m} = \vec{a}$

$\frac{12\,N}{6.0\,kg} = \vec{a}$

$\vec{a} = 2.0\,m/s^2$

$\boxed{\vec{a} = 2.0\,m/s^2 \text{ [Left]}}$

→ +

6) A net force of 34 N [forward] acts on a curling stone causing it to accelerate at 1.8 m/s^2 [forward] on a frictionless icy surface. Calculate the mass of the curling stone. [19 kg]

$\vec{F}_{NET} = 34\,N$
$\vec{a} = 1.8\,m/s^2$
$m = ?$

$\vec{F}_{NET} = m\vec{a}$

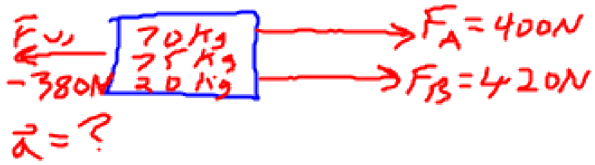
$\frac{\vec{F}_{NET}}{\vec{a}} = m$

$\frac{34\,N}{1.8\,m/s^2} = m$

$m = 18.8888888\,kg$

$\boxed{m \approx 19\,kg}$

7) Two athletes on a team, A and B, are practicing to compete in a canoe race. Athlete A has a mass of 70 kg, B a mass of 75 kg, and the canoe a mass of 20 kg. Athlete A can exert an average force of 400 N [forward] and B an average force of 420 N [forward] on the canoe using the paddles. During paddling, the magnitude of the water resistance on the canoe is 380 N. Calculate the initial acceleration of the canoe. [2.7 m/s^2 [forward]]



$$\vec{F}_{NET} = m\vec{a}$$

$$\frac{F_{NET}}{m} = \vec{a}$$

$$\frac{F_A + F_B + F_w}{m_A + m_B + m_c} = \vec{a}$$

$$\frac{400N + 420N - 380N}{70kg + 75kg + 20kg} = \vec{a}$$

$$\vec{a} = 2.666666 m/s^2$$

$$\vec{a} \approx 2.7 m/s^2 \text{ [forward]}$$

8) A person and an elevator have a combined mass of 6.00 x10^2 kg. The elevator cable exerts a force of 6.50 x 10^3 N [up] on the elevator. Find the acceleration of the person. [1.02 m/s^2 [up]]

$$F_g = mg$$

$$F_g = 6.00 \times 10^2 kg(-9.81 m/s^2)$$

$$F_g = -5886N$$

$$\vec{F}_{NET} = m\vec{a}$$

$$\frac{\vec{F}_{NET}}{m} = \vec{a}$$

$$\frac{\vec{F}_E + \vec{F}_g}{m} = \vec{a}$$

$$\frac{6.50 \times 10^3 N - 5886N}{6.00 \times 10^2 kg} = \vec{a}$$

$$\vec{a} = 1.023333 m/s^2$$

$$\vec{a} \approx 1.02 m/s^2 \text{ [up]}$$

9) The person in the question above rides the same elevator when the elevator cable exerts a force of 5.20 x 10^3 N [up] on the elevator. Find the acceleration of the person. [1.14 m/s^2 [down]]

$$\frac{\vec{F}_E + \vec{F}_g}{m} = \vec{a}$$

$$\frac{5.20 \times 10^3 N - 5886N}{6.00 \times 10^2 kg} = \vec{a}$$

$$\vec{a} = -1.143333 m/s^2$$

$$\vec{a} \approx 1.14 m/s^2 \text{ [down]}$$

10) An electric chain hoist in a garage exerts a force of 2.85 x10^3 N [up] on an engine to remove it from a car. The acceleration of the engine is 1.50 m/s^2 [up]. What is the mass of the engine? [252 kg]

y, x

$F_c = 2.85 \times 10^3 N$

$F_g = ?$

$m = ?$

$\vec{a} = 1.50 m/s^2$

$\vec{F}_{NET} = m\vec{a}$

$\vec{F}_c + \vec{F}_g = m\vec{a}$

$F_c + m\vec{g} = m\vec{a}$

$F_c = m\vec{a} - m\vec{g}$

$F_c = m(\vec{a} - \vec{g})$

$\frac{F_c}{\vec{a} - \vec{g}} = m$

$m = \frac{2.85 \times 10^3 N}{1.50 m/s^2 - (-9.81 m/s^2)}$

$m = 251.9893899 kg$

$m \simeq 252 kg$

11) A skydiver is jumping out of an airplane. During the first few seconds of one jump, the parachute is unopened, and the magnitude of the air resistance acting on the skydiver is 250 N. The acceleration of the skydiver during this time is 5.96 m/s2 [down]. Calculate the mass of the skydiver. [64.9 kg]

$F_f = 250 N$

$F_g = ?$

$\vec{a} = -5.96 m/s^2$

$m = ?$

$\vec{F}_{NET} = m\vec{a}$

$\vec{F}_f + \vec{F}_g = m\vec{a}$

$\vec{F}_f + m\vec{g} = m\vec{a}$

$F_f = m\vec{a} - m\vec{g}$

$F_f = m(\vec{a} - \vec{g})$

$\frac{F_f}{\vec{a} - \vec{g}} = m$

$m = \frac{250 N}{-5.96 m/s^2 - (-9.81 m/s^2)}$

$m = 64.935064 kg$

$m \approx 64.9 kg$

12) A 55-kg female bungee jumper fastens one end of the cord (made of elastic material) to her ankle and the other end to a bridge. Then she jumps off the bridge. As the cord is stretching, it exerts an elastic force directed up on her. Calculate her acceleration at the instant the cord exerts an elastic force of 825 N [up] on her. [5.2 m/s^2 [up]]

y, x

$F_e = 825 N$

55 kg

$F_g = mg$

$= 55 kg (9.81 m/s^2)$

$= 539.55 N$

$\vec{a} = ?$

$\vec{F}_{NET} = m\vec{a}$

$F_e + F_g = m\vec{a}$

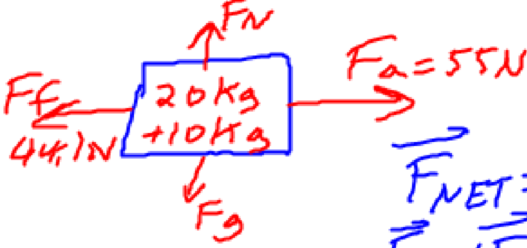
$\frac{F_e + F_g}{m} = \vec{a}$

$\vec{a} = \frac{825 N - 539.55 N}{55 kg}$

$\vec{a} = 5.19 m/s^2$

$\vec{a} \approx 5.2 m/s^2$ [up]

13) A 20kg and a 10kg block of identical material are connected by a light rope on a level surface. An applied force of 55 N [right] causes the blocks to accelerate. While in motion, the magnitude of the force of friction on the block system is 44.1 N. Calculate the acceleration of the blocks. [0.36 m/s^2 [right]]



$\vec{a} = ?$

$\vec{F}_{NET} = m\vec{a}$

$\vec{F}_a + \vec{F}_f = m\vec{a}$

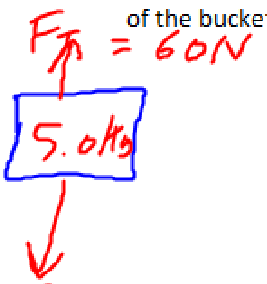
$\frac{\vec{F}_a + \vec{F}_f}{m} = \vec{a}$

$\vec{a} = \frac{55N - 44.1N}{30kg}$

$\vec{a} = 0.363333 m/s^2$

$\vec{a} \simeq 0.36 m/s^2$ [right]

14) Two buckets of nails are hung one above the other and are pulled up to a roof by a rope. Each bucket has a mass of 5.0 kg. The tension in the rope connecting the buckets is 60 N. Calculate the acceleration of the buckets. [2.2 m/s^2 [up]]



$F_g = mg$
$= 5.0kg(9.81 m/s^2)$
$= 49.05N$

$\vec{a} = ?$

$\vec{F}_{NET} = m\vec{a}$

$\vec{F}_T + \vec{F}_g = m\vec{a}$

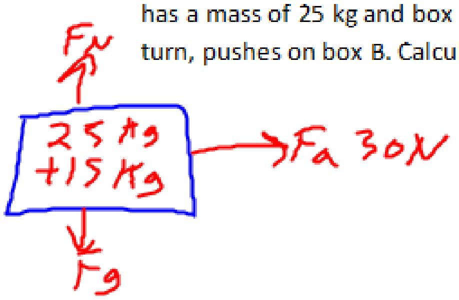
$\frac{\vec{F}_T + \vec{F}_g}{m} = \vec{a}$

$\vec{a} = \frac{60N - 49.05N}{5.0kg}$

$\vec{a} = 2.19 m/s^2$

$\vec{a} \approx 2.2 m/s^2$ [up]

15) Two boxes, A and B, are touching each other and are at rest on a horizontal, frictionless surface. Box A has a mass of 25 kg and box B a mass of 15 kg. A person applies a force of 30 N [right] on box A which, in turn, pushes on box B. Calculate the acceleration of the boxes. [0.75 m/s^2 [right]]



$\vec{F}_{NET} = m\vec{a}$

$\vec{F}_a = m\vec{a}$

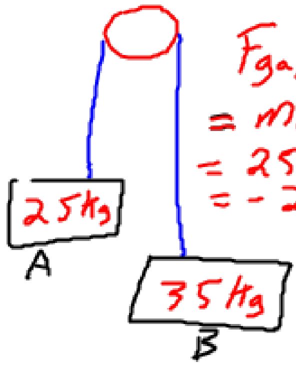
$\frac{\vec{F}_a}{m} = \vec{a}$

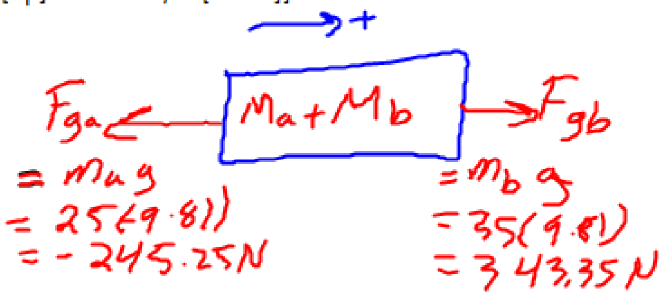
$\frac{30N}{40kg} = \vec{a}$

$0.75 m/s^2 = \vec{a}$

$\vec{a} \approx 0.75 m/s^2$ [right]

16) Object A and Object B are connected by a light rope over a light, frictionless pulley. A has a mass of 25 kg and B a mass of 35 kg. Determine the motion of each object once the objects are released. [1.6 m/s^2 [up] and 1.6 m/s^2 [down]]





$F_{NET} = F_{ga} + F_{gb}$

$F_{NET} = -245.25N + 343.35N$

$F_{NET} = 98.1N$

$\vec{F}_{NET} = m\vec{a}$

$\vec{F}_{NET} = m_{ab}\vec{a}$

$\frac{\vec{F}_{NET}}{m_{ab}} = \vec{a}$

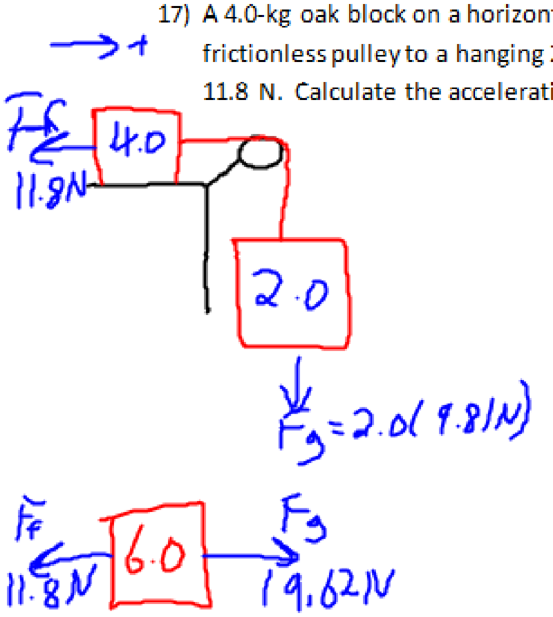
$\vec{a} = \frac{98.1N}{25kg + 35kg}$

$\vec{a} = 1.635 m/s^2$

$\vec{a} \approx 1.6 m/s^2$

m_a: 1.6 m/s^2 [up]
m_b: 1.6 m/s^2 [down]

17) A 4.0-kg oak block on a horizontal, rough oak surface is attached by a light string that passes over a light, frictionless pulley to a hanging 2.0-kg object. The magnitude of the force of friction on the 4.0-kg block is 11.8 N. Calculate the acceleration of the system. [1.3 m/s^2 [toward pulley], 1.3 m/s^2 [down]]



$F_{NET} = F_f + F_g$

$F_{NET} = -11.8N + 19.62N$

$F_{NET} = 7.82N$

$\vec{F}_{NET} = m\vec{a}$

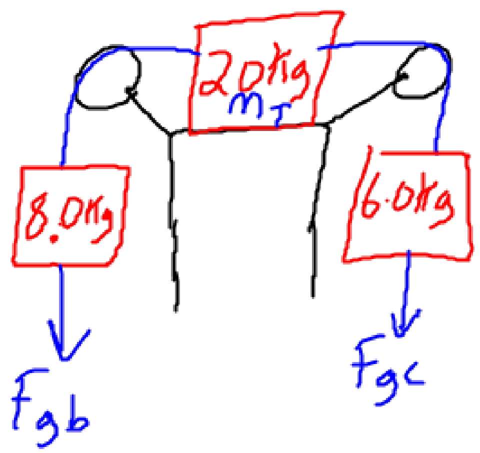
$\frac{\vec{F}_{NET}}{m} = \vec{a}$

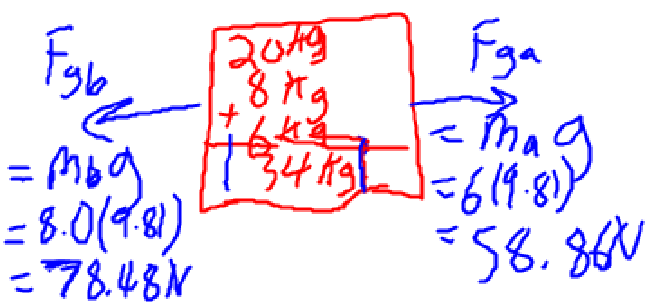
$\vec{a} = \frac{7.82N}{6.0kg}$

$\vec{a} = 1.30333 m/s^2$

Oak Block: 1.3 m/s^2 [Towards Pulley]
Hanging object: 1.3 m/s^2 [down]

18) A 20-kg truck tire (object A) is lying on a horizontal, frictionless surface. The tire is attached to two light ropes that pass over light, frictionless pulleys to hanging pails B and C (Figure 3.48). Pail B has a mass of 8.0 kg and C a mass of 6.0 kg. Calculate the magnitude of the acceleration of the system. [0.58 m/s^2]





$F_{NET} = F_{gb} + F_{ga}$

$F_{net} = -78.48N + 58.86N$

$F_{net} = -19.62\ N$

$\vec{F}_{NET} = m\vec{a}$

$\frac{\vec{F}_{NET}}{m} = \vec{a}$

$\frac{\vec{F}_{NET}}{m_T + m_B + m_C} = \vec{a}$

$\vec{a} = \frac{-19.62N}{20kg + 8.0kg + 6.0kg}$

$\vec{a} = -0.577059\ m/s^2$

$|\vec{a}| \approx 0.58\ m/s^2$

19) Explain why

(a) a swimmer at the edge of a pool pushes backward on the wall in order to move forward, and
(b) when a person in a canoe throws a package onto the shore, the canoe moves away from shore.

20) An object is resting on a level table. Are the normal force and the gravitational force acting on the object action-reaction forces? Explain your reasoning.

21) A rectangular juice box has two holes punched near the bottom corners on opposite sides, and another hole at the top. The box is hung from a rigid support with a string. Predict what will happen if the box is filled with water through the top hole and the holes at the bottom are open. Use Newton's third law to explain your answer.